Thinking Science

activities to sharpen your science and maths skills

Arvind Gupta

SCHOLASTIC

Thinking Science Arvind Gupta

It does not really matter if you are a budding scientist or if you shirk all things scientific, this book will have you engaged from the start. From the simplest paper-folding experiments in geometry to marble train tracks made out of broomsticks and plasticine, here is a range of unique and interesting activities. The easy-to-follow instructions and simple illustrations make this a valuable resource to reinforce maths and science concepts at home or in school.

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THINKING SCIENCE

Arvind Gupta has written a dozen books on science, translated over eighty books in Hindi and presented ninety-six films on science activities. His first book *Matchstick Models and Other Science Experiments* has been translated into twelve Indian languages. He has received several honours, including the inaugural national Award for Science Popularisation amongst Children (1988). At present, he is working in Pune, at the Inter-university Centre for Astronomy & Astrophysics Children's Science Centre. This is his second book published by Scholastic; the first, *Odds and Ends* (2007), was a book on science and craft activities.

THINKING SCIENCE

ACTIVITIES TO SHARPEN YOUR MATHS AND SCIENCE SKILLS

Arvind Gupta

Illustrated by
Avinash Deshpande

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INTRODUCTION

For many unfortunate students today textbooks have become synonymous with knowledge. What is tragic is that children lose sight of the fact that there is a vast, exciting world outside and may develop a distaste of learning.

Children are eternal explorers. In their free moments they are always experimenting and improvising, making and inventing things out of odds and ends. They learn a great deal from ordinary things found around the house. The main thing about scrap is that children can use it freely without adult admonishment.

This book lists a few innovative experiments for learning science and which make the act of acquiring knowledge fun and spontaneous.

Geometry by Paper Folding

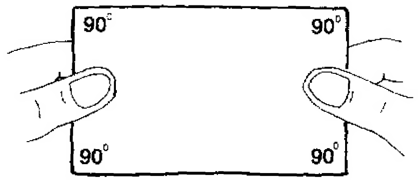
Paper folding is mathematical by its very nature. A sheet of paper starts as a plane. A fold produces a straight line—an intersection of two planes.

You will need

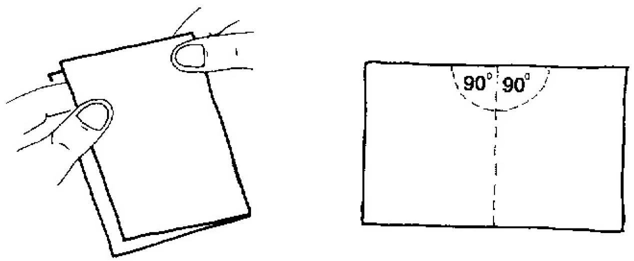
A sheet of paper

Here we go

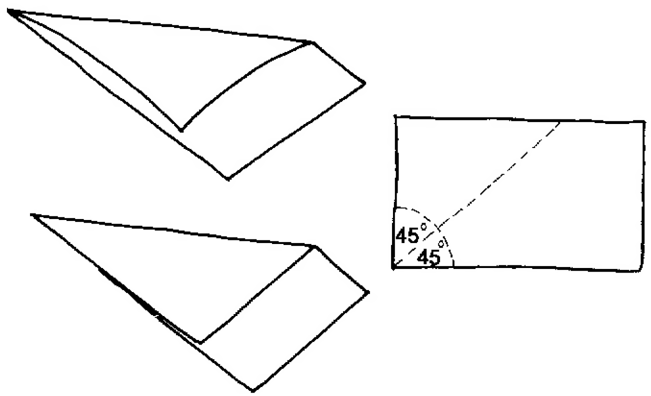
1. A simple right angle or 90 degrees is there in all paper sheets as every sheet has right-angle corners.



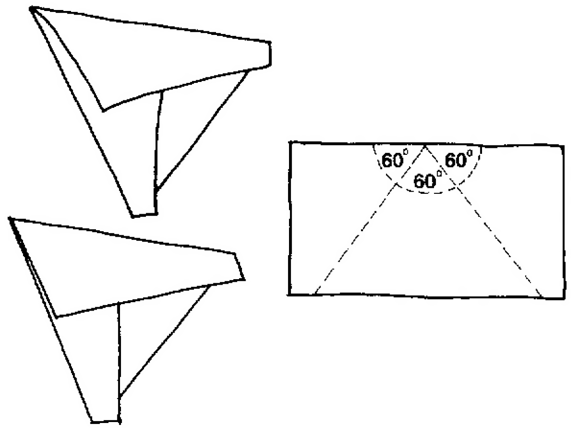
Most of these Geometric Exercises in Paper Folding have been inspired by a book of the same name, written by an Indian mathematician in 1893. His name was T. Sundara Row.



2. It's easy to see that a straight edge is 180 degrees by doubling it upon itself and seeing two exact right angles on either side of the crease.
3. A 45-degree angle is got by folding any right angle corner into half.



4. For a 60-degree angle, divide a straight edge 180 degrees into three equal angles. Take a point midway on the straight edge of the paper. Lift both



edges of the paper from this point and fold them to approximately 60 degrees.

Before creasing, ensure that the edges are flush with the folds to be creased forming accurate 60-degree angles.

Paper Diamonds

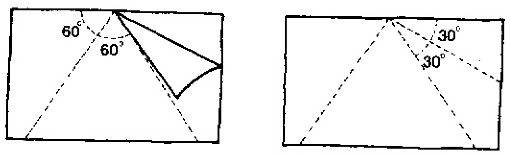
Let's carry on folding—from experimenting with angles we can move on to see a series of nesting diamonds.

You will need

A sheet of paper

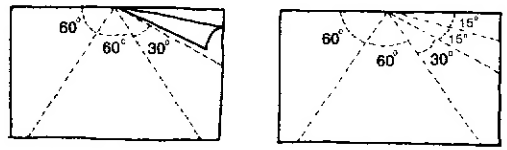
Here we go

1. A 30-degree angle can be got in two ways. Either you could fold a right angle into three equal parts, or else, fold the 60-degree angle such that one edge doubles on the other.

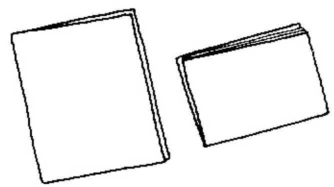


2. A 15-degree angle can be got by halving the 30-degree angle. This can be simply done by doubling one edge over the other.

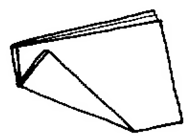
You do not need to use the protractor, the compass or any other aid from the geometry box for folding these angles. By combining the angles, you can get several more. For instance, 105 degrees can be got by adding 90 and 15. Angle of 75 degrees can be got by subtracting 15 from 90.



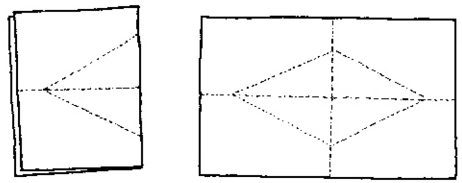
3. Want to fold a diamond? Fold a sheet first into two and then into four.



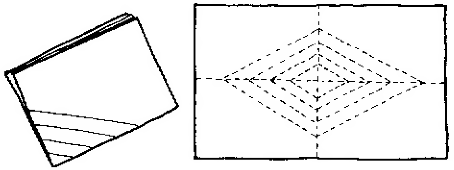
4. Crease a triangle at the four-fold corner.



5. On opening the sheet, you'll see an elegant rhombus in the middle.



6. If you make several parallel creases in the four-fold corner, then on opening up you will see a diamond in a diamond in a diamond—a series of nesting diamonds .



Knotty Pentagon

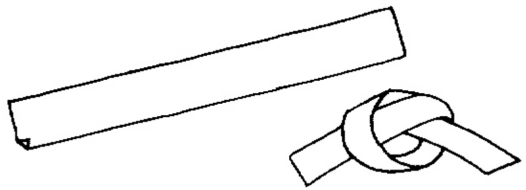
Folding a paper into five equal parts can prove tricky, especially a regular polygon with an odd number of sides.

You will need

A sheet of paper

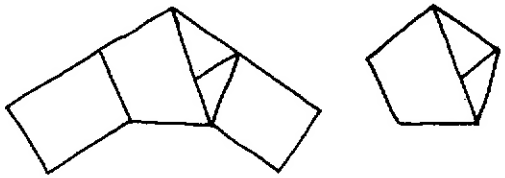
Here we go

1. How do you fold a regular pentagon? We often tie knots in pyjama strings and ropes, seldom noticing that a tight knot takes the shape of a pentagon.



Take a long rectangular strip of paper and tie the two loose ends into an ordinary knot.

2. Gently pull the ends to tighten the knot and you'll be surprised to see a very neat knotty pentagon.



Hex Cob

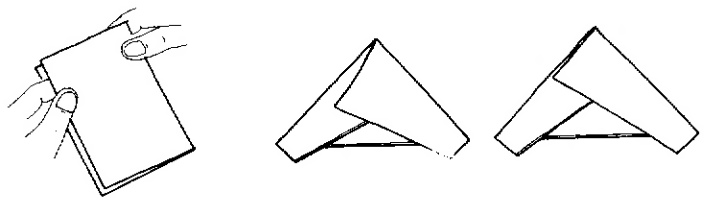
Now try folding a regular hexagon.

You will need

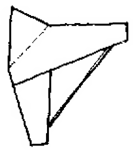
A sheet of paper

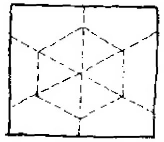
Here we go

1. First fold a sheet into two.
2. Fold the doubled-up straight edge (180 degrees) into three equal parts of 60 degrees each.
3. Ensure that the double edges are flush with the folds to be creased.

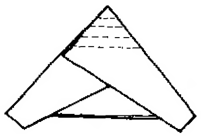


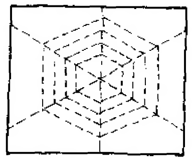
4. Fold the six-layer corner into a triangle.
5. On opening you'll see a regular hexagon in the middle.





6. On folding several parallel creases and opening up you'll see a set of nesting hexagons.
7. The nesting hexagons resemble a cobweb.



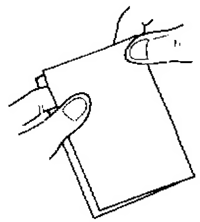


Folding an Octagon

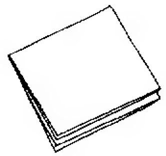
After the pentagon and hexagon, we can naturally move on to the octagon.

You will need
A sheet of paper

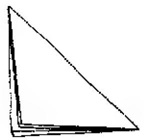
Here we go
1. Fold a sheet first into two.



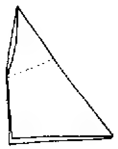
2. Then into four.



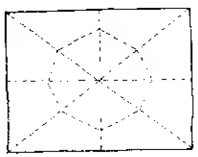
3. Crease the four-fold corner again into a triangle to make eight folds.



4. Crease the eight-fold corner sharply.



5. On opening you'll find a regular octagon in the centre. You'll also see that the central angle of 360 degrees is divided into eight segments of 45 degrees each. You can also try folding nesting octagons.

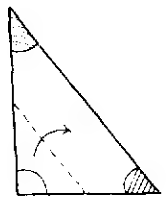


Angles of a Triangle

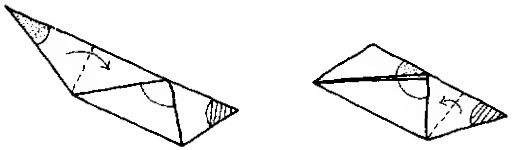
This simple exercise in paper folding will show you that the sum of the interior angles of a triangle is 180 degrees.

You will need
A sheet of paper

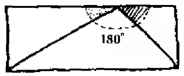
Here we go
1. Cut a triangle out of a piece of paper.



2. If you fold over the corners as shown in this sequence then you can easily make the three angles fit together to form a 180-degree angle.



3. When the angles are placed together they make a straight line. This means they total 180 degrees. The sector forms a semicircle.



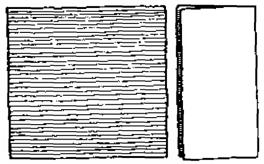
Self-locking Parallelogram

Let us now move on to the parallelogram.

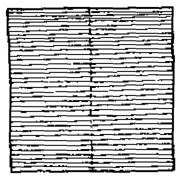
You will need
A sheet of paper

Here we go

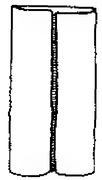
1. Take a square piece of paper and fold a crease in the middle.

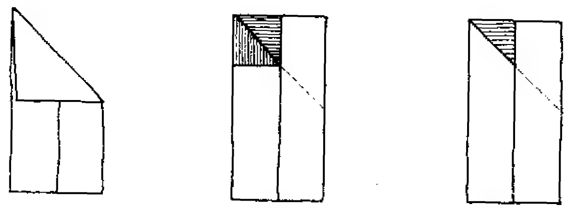


2. Open it.

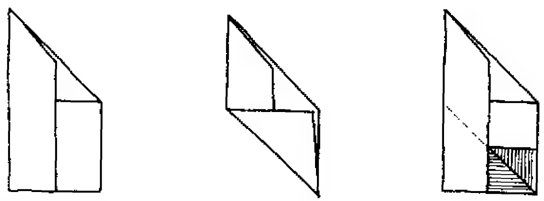


3. Now fold the two edges of the square inwards to touch the middle crease to make a vertical rectangle.
4. Fold the top right angle corner into half. Crease and open up.
5. On opening you'll find a small triangular flap.
6. Fold it inwards.



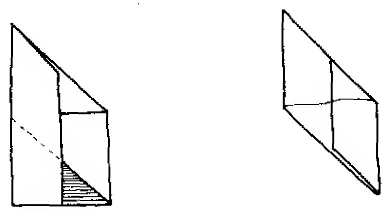


7. Now insert the right hand corner between the folds of the left vertical rectangle.
8. Repeat the same process for the lower left corner of the rectangle.
9. First, fold it into half. Open the crease.
10. Fold the small triangular flap inwards.



11. Insert the lower left corner between the folds of the right vertical rectangle.

The final folded shape becomes a self-locking parallelogram. The opposite sides and angles are equal. One surface of this parallelogram is plain and smooth while the other surface has four pockets.

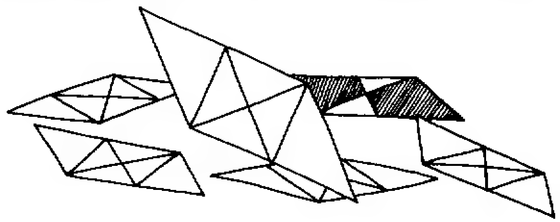


Self-locking Cube

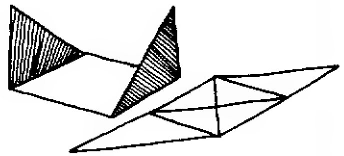
A cube can be used as a dice and put to other uses as well.

You will need
A sheet of paper

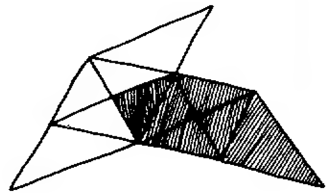
Here we go
1. Fold six self-locking parallelograms of the same size using the procedure described on the previous pages. As parallelograms can have left or right orientations, ensure that all the six parallelograms have the same orientation.



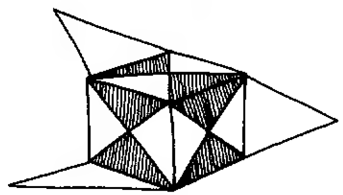
2. Each parallelogram can be viewed as having a square in the middle and two triangular flaps on the ends. Fold the triangular flaps of all the parallelograms towards the plain side, such that the pocket face is an exact square. Now all these six folded parallelograms—with square faces and triangular flaps—will be assembled into a regular cube. There will be twenty-four pockets and twelve flaps in all.



3. Start with two parallelograms. Insert one flap of the first into a pocket of the second.

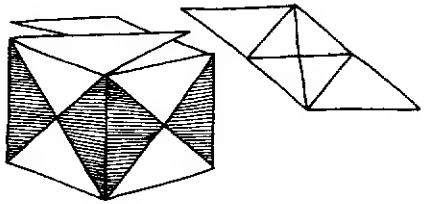


4. Take the third parallelogram and insert both its flaps—one in each of the previous

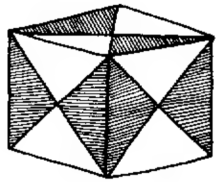


parallelogram pockets. Thus one corner of the cube will be assembled.

5. Continue assembling taking care that all the flaps come over the square faces and get inserted in the pockets.



6. No flap will be inside the cube. No glue is required. Coloured cubes can be made using different colours of glazed paper. Small and stiff cubes make beautiful dices.



Postcard Structures

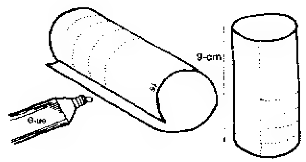
Everything has a structure. The human body, buildings, bridges, animals—all have a skeletal frame which bears the load. Using old postcards, we'll explore a few structures.

You will need

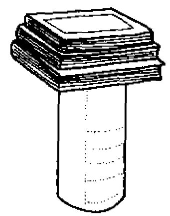
Four postcards	Glue
Books	Two bricks
50-paisa coins	Tin pan

Here we go

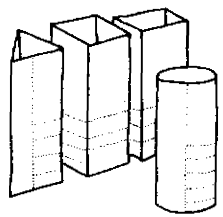
1. All postcards measure 14cm x 9cm. Fold and glue a postcard into a 9cm tall cylinder.



2. It doesn't look very strong. How much load can it support? Make a guess. Now slowly pile books on this column until it collapses. Place the books in the centre so that they don't tip off. The 9cm tall postcard cylinder is able to support nearly 4kg of load.

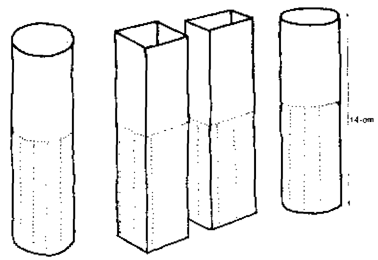


3. Try folding 9cm tall columns of different cross-sections—triangular, rectangular, square, and oval. Which cross-section will sustain the most load? Why? Columns of which cross-section do you most frequently encounter in daily life?

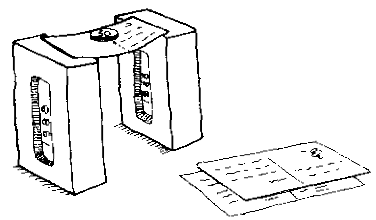


4. Fold postcards in various cross-sections to make 14cm-high columns. Which cross-section is the most efficient? Make two columns of the same cross-sectional area, but one tall and the other

short. Which supports more load? For the same cross-section of column, how does load bearing depend upon height?

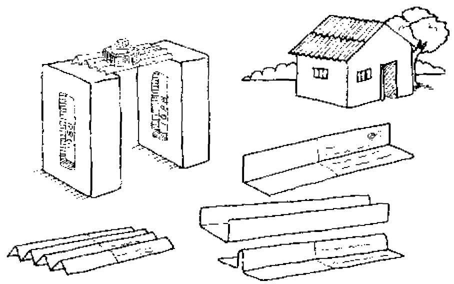


5. Stand two bricks 12cm apart. Place a postcard on top of the bricks such that 1 cm length of the postcard sits on either brick. Now place 50-paisa coins (5gm each) in the middle of the postcard. The postcard sags a little bit. With every additional coin the card sags some more. When the load is around 40gm, the postcard caves in and falls down.

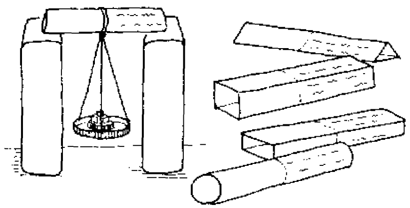


6. Crease the postcard in the middle along the length to make a right-angle section. Place it similarly on

the bricks and see the load it can support. Can a crease help in strengthening a structure? Test a U-shaped channel section and a T-beam. Do different sections support different loads? Fold four pleats in a postcard and place this corrugated postcard on the bricks. How much load can it support? Are you surprised that it can now support almost a kilogram. So, it's not just the material but the shape in which it has been arranged which gives the structure its strength and rigidity. Corrugated tin roof sheets are a common example of increased strength.



7. Place the 14cm-long postcard columns as beams between the two bricks. Suspend an empty tin pan and place weights on it. Which cross-section of beam supports the maximum load?



Eggshell Tripod

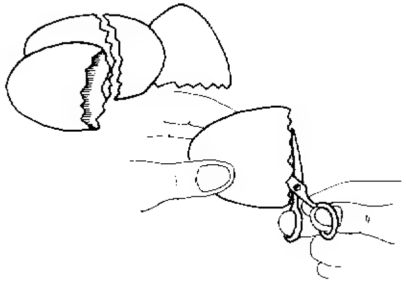
Eggs have very thin shells but nature designed the eggshell as a strong vault to protect the live embryo inside. Shell structures are usually very strong and you can test this using three broken eggshells.

You will need

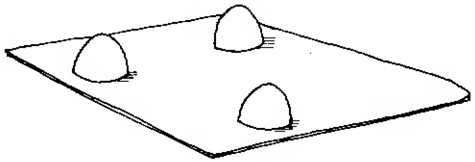
Scissors	Three eggshells
Books	Towel

Here we go

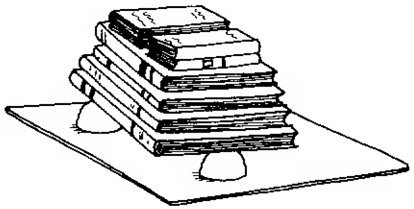
1. Using scissors nip the eggshells bit by bit to even out the zigzags, and to get a smooth circular rim. Carefully rub the circular rim on a cement floor to even out the remaining zigzags.



2. Place three such eggshells on a doubled up towel, which will act as a cushion. Now make a guess estimate of the weight which this egg tripod will be able to withstand.



3. Keep placing books on the tripod until the eggshells crush under their load. How close was your guess?



Nature is very economical in its use of material. Human beings have learnt a great deal about structures from nature's optimal designs.

Geodesic Dome

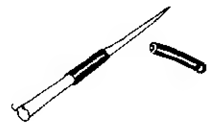
A geodesic dome looks like a triangulated igloo. And triangles being the most stable polygons, the geodesic dome is one of the strongest structures. A geodesic model can be easily made using cycle valve tube joints of four, five and six, and three different sizes of broomsticks.

You will need

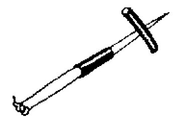
A cycle valve tube	Coconut broom sticks
A thorn or big needle	A craft knife or blade

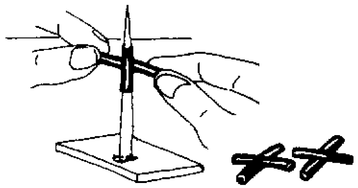
Here we go

1. Take two bits of cycle valve tube, 2cm long. Weave a thorn or needle through the hole of one valve tube.

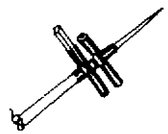


2. Poke the thorn through the middle of the second valve tube.
3. Stretch it and slip it over the first valve tube. This is the joint of four. You'll need fifteen such joints.

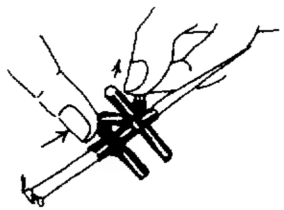




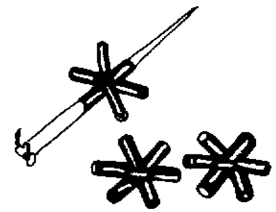
4. To make a joint of six, slip a third valve tube on the first valve tube to make an H shape.



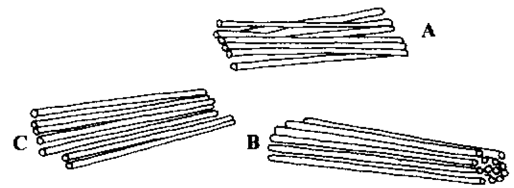
5. Insert a broken matchstick in any of the free legs of the second valve tube. Weave this matchstick through the centre of the third valve tube.



6. Remove the joint of six from the thorn. You'll require twenty-five joints of six.
   You'll also require six joints of five. For this make joints of six, and use only five legs.



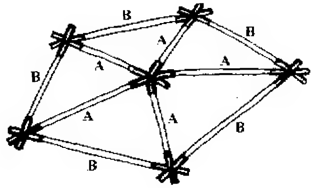
7. You'll need three different sizes of struts. Cut them out of the coconut broomsticks.
   Strut A = 6.2 cm, thirty units
   Strut B = 7.5cm, forty units
   Strut C = 7.23cm, fifty units
   Using these sizes of struts the approximate diameter of the dome will be 30cm. The relative proportions of the three struts A : B : C is 35 : 41 : 40. Using these proportions for strut sizes you can build a smaller or a bigger dome.



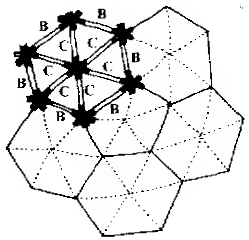
A football is a good model for a geodesic dome. You can see a football is made up of pentagons and hexagons. Divide these pentagons and

hexagons into triangles with a sketch pen to simulate a geodesic.

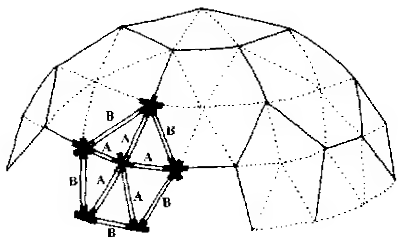
8. Start assembling as shown.



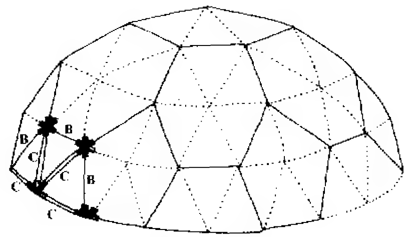
9. Build five hexagons on the five sides of the top pentagon. Complete a circle before beginning the next.



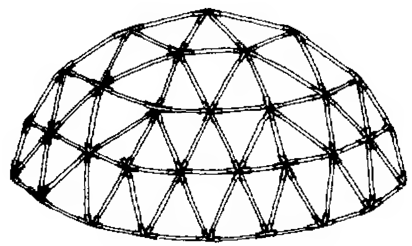
10. Assemble five pentagons into the corners.



11. Finally assemble the bottom half hexagons.



This is the final assembly of the geodesic dome. The great American designer, Buckminster Fuller, is credited for designing and popularising the geodesic dome. Since then it has been put to lots of different uses. With the invention of the electron microscope scientists discovered that the structure of the protein virus was a geodesic.



Pump from the Dump

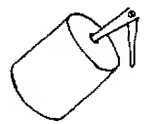
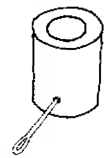
This pump consists of a piston, cylinder and two valves all salvaged from odds and ends. With each motion of the piston, water will leap out in large gushes.

You will need

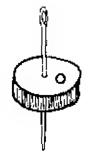
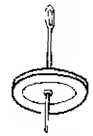
A film can	One rupee coin
A mineral water bottle cap	Cellotape
Ordinary hand tools	Bicycle spoke
Ballpoint-pen refill	Scissors
Nuts	

Here we go

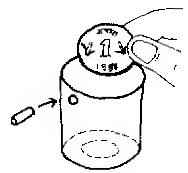
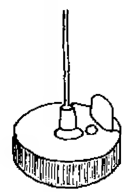
1. Make a hole in the base of the film can by rotating a scissor point. The hole should have a diameter of 1cm.
2. Make a hole near the open end of the bottle. A ballpoint-pen refill must press fit in this hole.

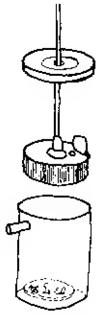
3. The piston is made out of a mineral water bottle cap. These caps fit snugly into the film can. Make a 5mm hole for the valve. Make a small hole in the centre to fix the cycle spoke.
4. Make a hole in the lid of the film can. This hole should be free fit for the up-down motion of a bicycle spoke.

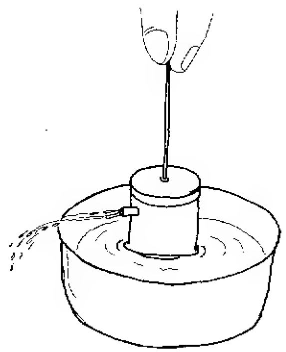
5. Drop a one-rupee coin in the film box. The coin will be the suction valve. Fix a small refill for the delivery pipe.
6. Fix a 15cm cycle spoke with two nuts to the cap. The spoke will be the connecting rod. Stick a piece of cellotape so that it can open/close the hole. This flap is the delivery valve.

7. This is the final cylinder-piston assembly of the pump.



8. Place the pump in a bowl of water and move the spoke up/down. After just a few thrusts, large quantities of water will gush out.



Marble Train

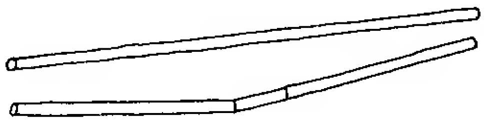
When the soft portion of a broom has worn out and is reduced to a stub, it is still of great use for making the track of a marble train.

You will need

An old soft broom
Some clay
Marbles

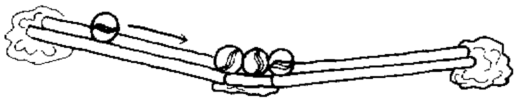
Here we go

1. Take two sticks from the broom (about 30 cm long) and bend them 2cm in the middle. Embed the ends into lumps of plasticine or clay.

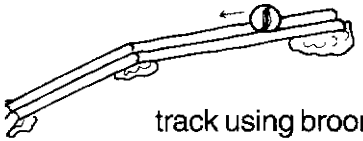


Support the middle portion of the sticks with a bit of clay too. The ends should be 3cm higher than the middle. The distance between the sticks should be 5mm or so such that a marble can roll smoothly on the track. Place three marbles at the 'cup' of the track.

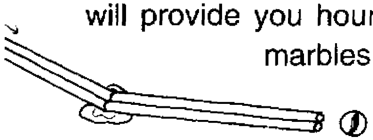
2. Now roll one marble down the left incline. It will hit the three marbles.



3. On impact only one marble will be ejected up the right incline. Try rolling down two marbles together. On impact only two marbles are ejected up. This illustrates the principle of conservation of momentum.



4. You can also make a long and winding marble track using broomsticks and bits of clay. The bends and the incline should be gradual. Make stations, crossings, bridges and tunnels to give your marble train a realistic look. This marble train will provide you hours of fun as you see the marbles roll down the tracks.



Flexagons

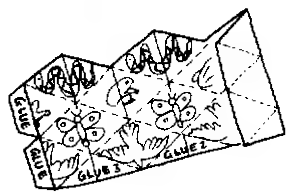
The flexagon is an amazing model. Each time that it flexes about its centre a different picture comes into view. It can be used to depict any four-stage cycle or sequence. Four flexagon networks printed on thin card sheets are stapled in the middle of the book. The card sheets have the printed network on one side. The reverse side is plain white.

You will need

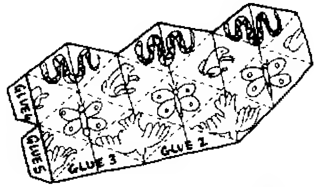
Flexagon network Card sheets (see end of the book)
Glue

Here we go

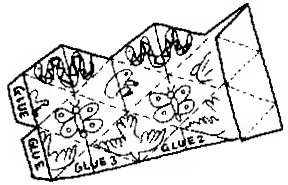
1. First cut out the network precisely along the outline. Paste on thin card.



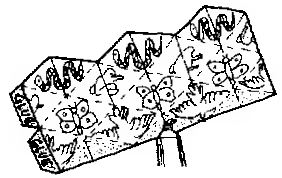
2. Fold all eight diagonal lines (marked with dashes) away from the picture.



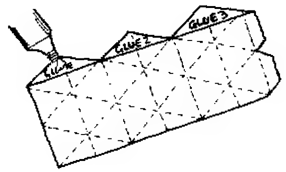
3. Fold all six vertical lines towards the picture. First try to assemble the model without applying glue.



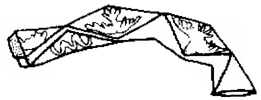
4. When you can see how it fits together glue in order of 1, 2, 3, 4, 5. Glue 1, 2, 3 on the picture side.



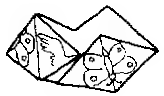
5. Apply glue also to the three triangular hills on the plain side of the sheet. These have not been marked on the network.



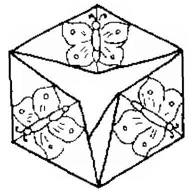
6. Glue 1 of picture side to 1 of plain side. Do the same with 2 and 3, to get the chain in.



7. Apply glue to flaps 4 and 5. They go inside the pocket to complete the ring. The use of a quick-dry strong adhesive gives better results.



8. This is the finished model. Once it is dry, flex it to glory.



More about Flexagons

The printed card flexagon networks have the following stages.

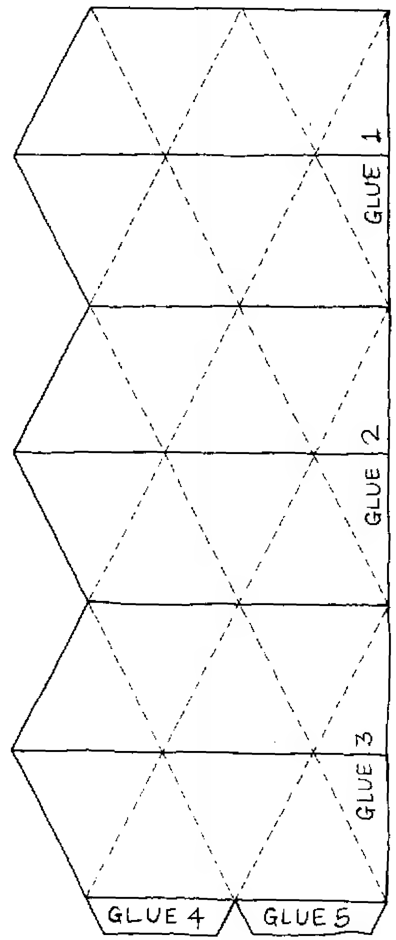
WATER CYCLE: (a) the sun evaporating water from the oceans leading to (b) cloud formation which results in (c) rainfall which (d) fills all the reservoirs with water.

EVOLUTION: (a) 3,000 million years, early sea with algae and simple water plants (b) 600 million years, fishes, molluscs and crustaceans (c) 230 million years, dinosaurs (d) 70 million years, emergence of mammals including human beings.

A BUTTERFLY'S LIFECYCLE: (a) female laying eggs (b) caterpillar emerging from egg/moulting (c) pupa and (d) a butterfly emerging from the pupa.

FOOD CHAIN: (a) butterflies (insects) eaten by (b) frogs who in turn are eaten by (c) snakes, who form the food for (d) eagles (birds).

Actually the flexagon is a very powerful model for depicting any sequence or cycle—and nature is full of them. A plain network is given. Trace it and make several cycles/chains on your own. Sticking the network on thin cloth (such as an old sari) and then cutting, folding and pasting, makes a very long-lasting flexagon.



Plain Paper Flexagon

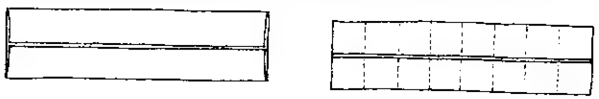
Having caught the flexagon bug you will enjoy making many more. Here is a no-network, no-nonsense way of folding flexagons out of plain paper. No gluing is necessary.

You will need

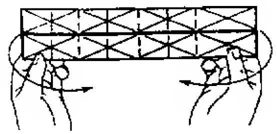
A rectangular sheet of bond or any stiff paper (made up of two squares)
Pencil Scale

Here we go

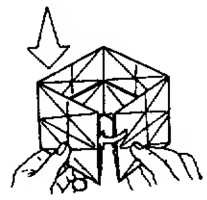
1. Crease the midline along the length, and fold the long edges to this midline.
2. Fold eight equal segments along the width.



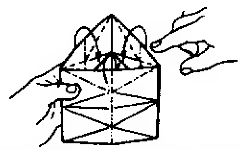
3. With the help of a pencil and scale, first draw the diagonal lines as shown. Then crease them well.



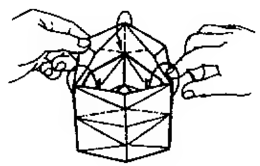
4. Bring the left and right sides together and insert one side inside the other, thereby making a three-dimensional prism.



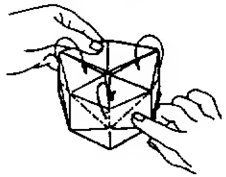
5. Push in the three triangular areas on top of each other.



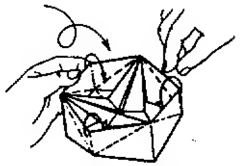
6. Press all the three top points down and through the centre. The next row of triangles will assume a similar shape.



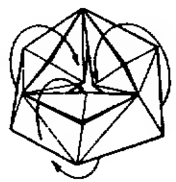
7. Once again, press all the three top points down and through the centre.



8. Turn the model over and push in the three triangular areas on top of each other.



9. This will complete the flexagon. To make it rotate hold it on either side and twist the outer edges in towards the centre, so that the inner surfaces appear.



Every time you rotate the flexagon a different facet is exposed. You can depict a cycle, chain or sequence by drawing a different picture on each of the facets.

Bow Drill

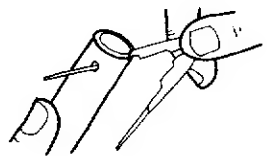
Normally we see things with our eyes. But we continue to see a thing for a little while longer even after it has been removed from sight. This is called 'persistence of vision'. The principle of the ancient bow drill, still in use by carpenters, can be incorporated into an ingenious folk toy to demonstrate the persistence of vision.

You will need

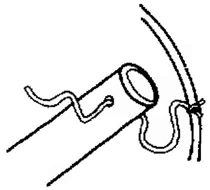
An empty cotton reel	Thread
Divider	Ball pen refill or reed
Bicycle spoke	Card and glue

Here we go

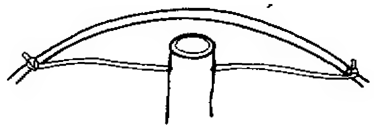
1. Take an empty cotton thread reel. Make a hole about 1cm from one end with the point of a divider.



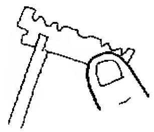
2. Weave a thread through this hole.



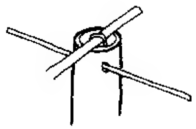
3. Tie the ends of the thread to the two ends of a cycle spoke bent into an arc. The bow string should be slightly loose.



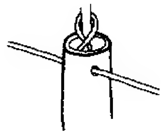
4. An old ball pen refill or reed 10 cm long is split for about 1 cm on one end.



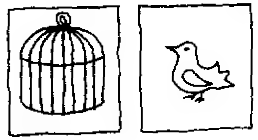
5. Insert the other end of the reed inside the reel and yank out the thread.



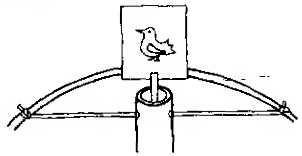
6. Rotate the reed by 180 degrees and insert it inside the reel so that the thread loops once around the reed.



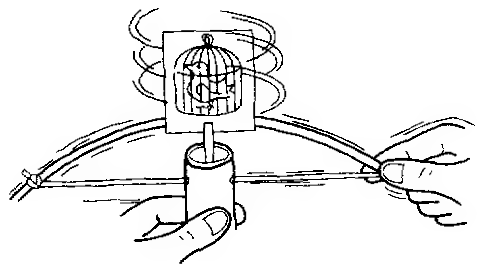
7. Make a bird and a cage on either side of a 3 cm square card sheet.



8. Wedge the card in the slit on top of the reed.



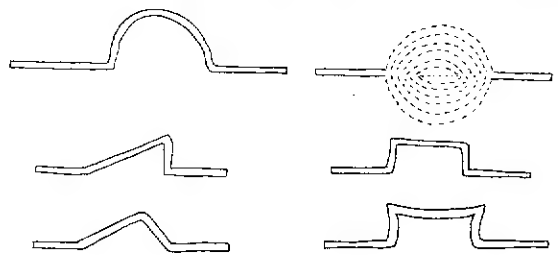
9. On moving the bow to and fro, the reed twirls and the bird appears to be encaged.



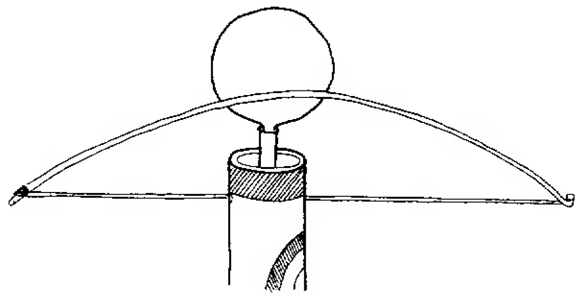
The bow drill converts the straight line motion of the bow, into the rotary motion of the reed.

If, however, the reel is held in one hand and the reed rotated, it moves the bow to and fro. This familiar mechanism is used in all radio knobs, where rotary motion of the bow is converted into the straight line motion of the pointer.

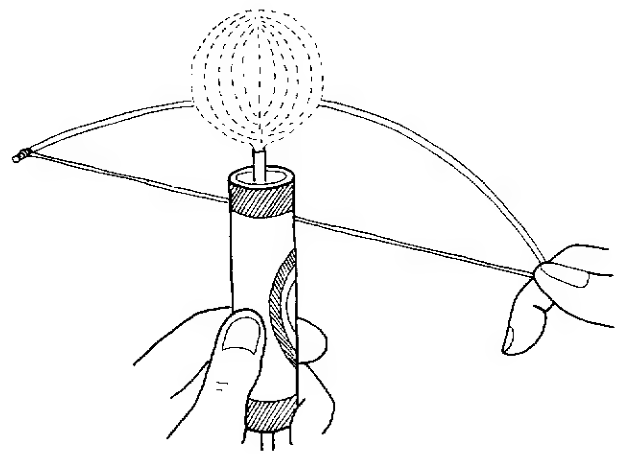
10. This mechanism can also be used for producing rotation of solids. Take pieces of soft wire and bend them in sections as shown . Now twirl them between your fingers to produce a solid of rotation.



11. Make a circular hoop of wire and wedge it in the reed of the bow drill. When you rotate it, you will see the spherical profile of a revolving circular hoop.



12. If the wire hoop is bent into a rectangular shape, then on rotation you will see a cylinder.



Silent Motion Film

If you wave a smouldering matchstick in a dark room you will see a continuous curve of light. By moving your hand fast enough you can make a glowing figure of eight, circles or ovals.

Try making a flip book in which pictures change very gradually from one page to the next. When you ruffle the pages under your thumb, the pictures blend into one another and there is the illusion of motion. It is very much like looking at a film without sound.

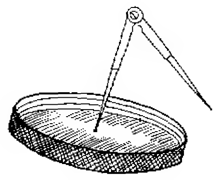
Here is another way of making a short, soundless motion film.

You will need

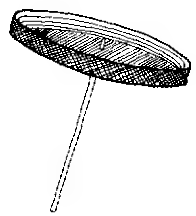
An old plastic jar lid	A card	
A ball pen refill	A divider	Glue

Here we go

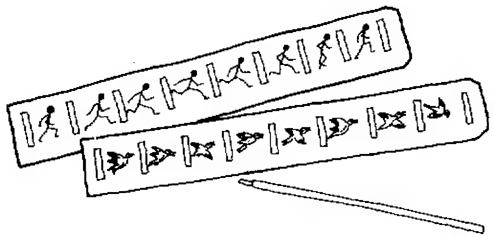
1. Take an old plastic jar lid about 10cm in diameter and make a hole in its centre with the point of a divider.



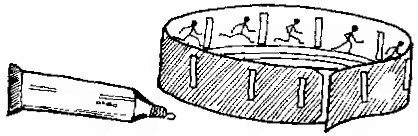
2. Insert the tip of a ball pen refill in this hole. The jar lid should rotate smoothly on the refill tip pivot.



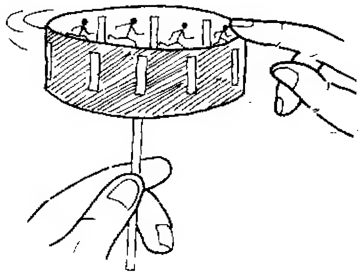
3. Cut a strip of card long enough to go around the circumference of the lid. Draw gradually changing pictures on this strip. Cut slits between the pictures.



4. Glue the strip on the rim of the lid with the pictures inside.



5. On rotating the lid you'll see an animated motion picture of a man running. You could make a bird fly or a joker throw up eggs. For a clearer view, colour the outside of the slit strip black.



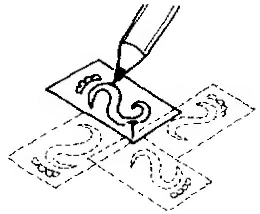
Mirror Puzzles

Nature is replete in symmetry. A butterfly's wings are a good example. One half of the wings can be folded on to the other half to match exactly. The fold then becomes the line of symmetry.

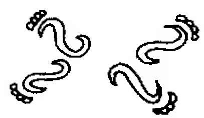
You will need

A postcard
A mirror
Compound leaves

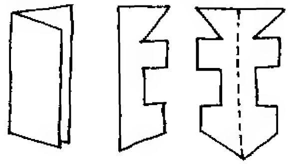
Here we go



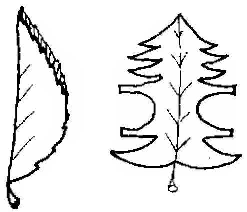
1. Cut a pattern on a postcard. Push a pin in one corner and draw the pattern.
2. Rotate a quarter turn and draw again. Repeat it. It shows rotational symmetry.



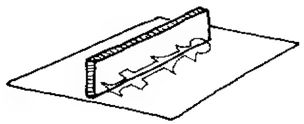
3. Fold a paper in half. Cut shapes along the edges. Open the paper to see the space pattern.



4. Which is the line of symmetry? You can use leaves, too, for this purpose. Invent lots of new shapes.

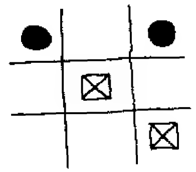


5. Draw a shape and put a mirror beside it so that the shape doubles itself.

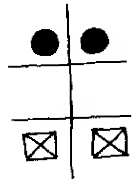


6. Search for compound leaves that look as if they have been doubled up in a mirror.

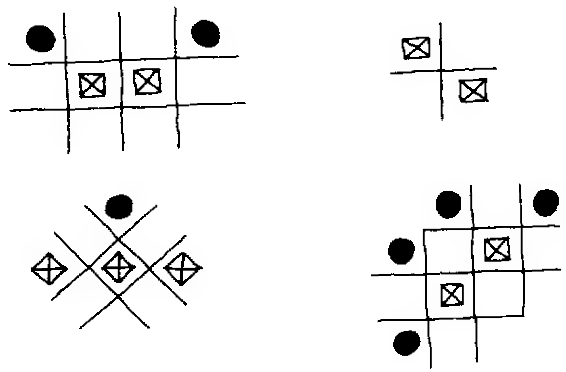
7. Stand the mirror on this **Master Pattern.** Slide and turn the mirror to see the patterns change.



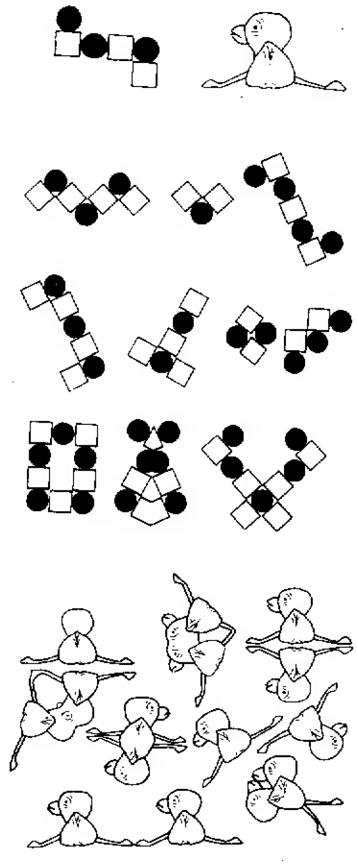
8. Now orient the mirror on the **Master Pattern** in such a way that you can see the patterns which match with this. Is your mirror on a vertical line facing to the right?



9. Place the mirror on the **Master Pattern** in different orientations to get the other patterns.



10. Two Mirror Masters—one composed of squares and dark circles, and the other of a chick—are given here. Each time you have to place your mirror on the mirror master only, in various orientations and get all the patterns given below. You'll be able to get most of them. But some of the patterns have been included to trick you. They are not simply hard, but they are impossible. Can you locate the impossibilities? If you have enjoyed these mirror puzzles, why not make some of your own?



Some shapes have more than one line of symmetry. Some have none. A square has four lines of symmetry. Place a mirror strip on each of these lines and see how the square remains

unchanged. Can you place the mirror to make squares of different sizes?

Any line which passes through the centre of the circle is a line of symmetry, but can you place the mirror to make different sized circles?

Develop an eye for looking at symmetries. You'll find them everywhere—even in alphabets and numerals. Which alphabets have no line of symmetry? Which have one? Two?

Write your name in capital letters. Find the letters which have at least one line of symmetry.

Drop and Bulb Microscopes

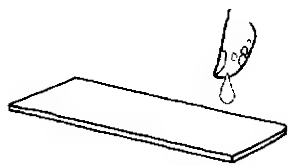
There is something magical about a magnifying glass as it enlarges small and sundry objects for us. Let us make some microscopes of our own.

You will need

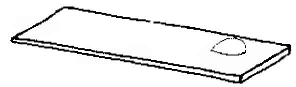
Glass slides	Various sizes of bulbs
Water	Oil
A bit of glycerine	

Here we go

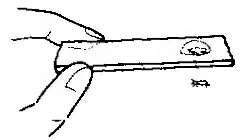
1. Take a slide or broken glass pane and rub a thin layer of oil. Gently place a drop of water on the slide.



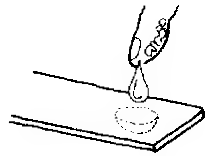
2. The water drop 'sits' on the slide and makes a plano-convex lens.



3. Look at some small print or an ant through the drop lens. Do the ant's legs appear any bigger? Quickly invert the slide, so that the drop instead of 'sitting up' will be 'hanging down'.

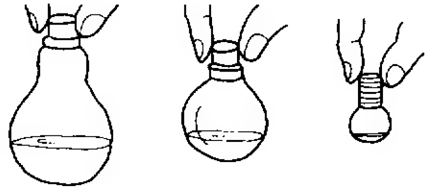


4. Place another drop on the slide right on top of the previous drop to make a double convex lens.

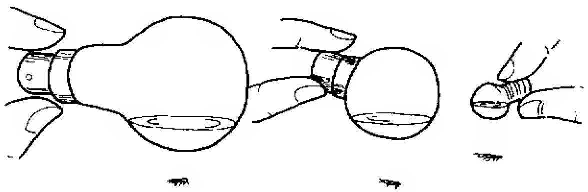


5. Does the 'hanging–sitting' combination make any difference to the magnification? Repeat the experiments using drops of glycerine and coconut oil instead of water. Does it make any difference to the clarity, magnification?
6. Remove the filaments of a 40 watt, zero watt and a torch bulb by carefully hammering at the resin ends. Half-fill the bulbs with water. The water

surface in combination with the bulb curvature makes a plano-convex lens.



7. Observe the same object through all the three bulbs. Which bulb magnifies the most? You'll see that the torch bulb, with the least radius of curvature, magnifies the most. You can now see that magnification is inversely proportional to the radius of curvature.



Ray Model

Let us unravel the mysteries of a convex and concave mirror and understand their underlying principles.

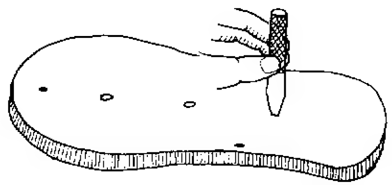
You will need

An old rubber slipper

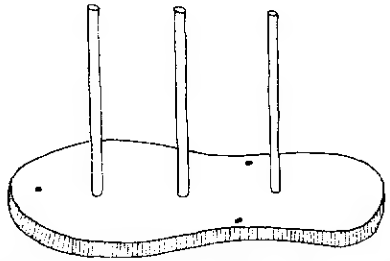
Broomsticks or pencils

Here we go

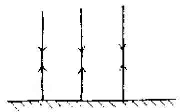
1. Punch out three holes 5cm apart on an old rubber slipper. Press fit 20cm long broomsticks or pencils in these holes.



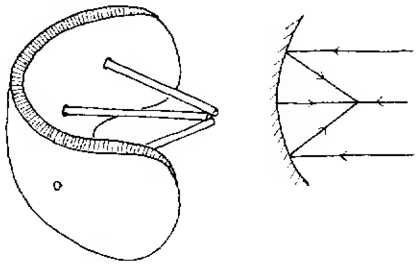
2. When the slipper is lying flat, the sticks stand upright.



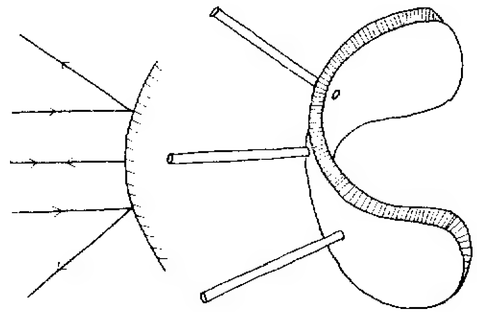
3. Suppose the rubber slipper was a plain mirror strip, then light rays striking it at right angles will again retrace their path as in the ray diagram.



4. What would happen if instead of a plain mirror you had a concave mirror? Just bend the rubber slipper inwards and see. The three sticks now converge at a point called the **focus**.



5. What would happen if instead of a plain mirror you had a convex mirror? Just bend the slipper the other way and you'll see the sticks diverging.



As glass cannot be flexed and rays are invisible, this model will be of some help in explaining the concept of ray diagrams through curved mirrors.

Roulette

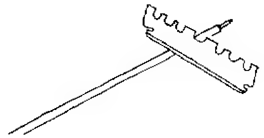
Empty ball pen refills are not for throwing, for they make beautiful bearings.

You will need

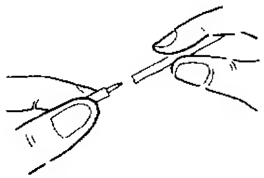
Cardboard	Old ball pen refill	Glue
Hole punch	Rubber from an old slipper	

Here we go

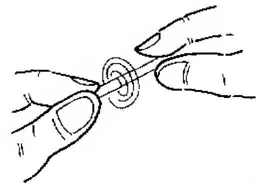
1. Cut a used refill about 1 cm from the top.



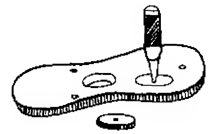
2. Insert the plastic refill on its metal tip.



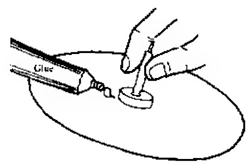
3. The refill on its own tip makes a fine bearing.



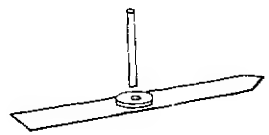
4. Punch a 2mm hole in a rubber disc cut out of an old slipper.



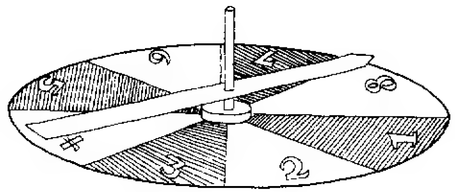
5. Stick this disc at the centre of a 20cm diameter cardboard. Insert a 1cm refill with the brass tip in the disc hole.



6. Cut a 20cm-long and 1cm-wide pointer out of cardboard. Stick another rubber disc with a hole at its centre.



7. Insert a 8cm long plastic refill in this disc. Place the refill in the pointer on the refill tip in the middle of the cardboard disc. On twirling the pointer refill, the pointer rotates very smoothly on the disc. Place a circular paper disc divided into eight equal parts on the cardboard disc. The roulette has now become a dice of eight.



By changing the paper disc you can make a dice of any number. You can also create a number of matching games, where one can match colours, shapes or other things.

Broomstick Table

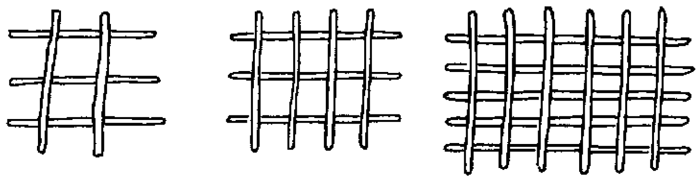
Tables are often learnt by rote. This repetitious drill might help quick recall but it kills the whole joy of learning. With only eighteen equal-length broomsticks you could discover the whole world of tables.

You will need

18 equal-length broomsticks
A square-ruled sheet

Here we go

1. Lay one broomstick and place another one across it. At how many points do they meet? Obviously, one.
   So, 1 x l = 1. If two vertical broomsticks are placed criss-cross over three horizontal broomsticks then they have six junctions. So, 2 x 3 = 6.

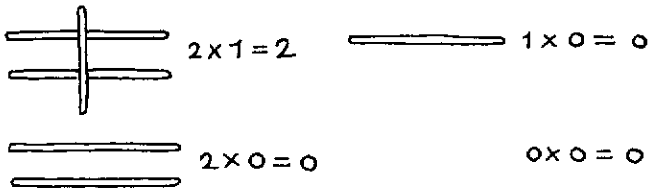


$2 \times 3 = 6$ $4 \times 3 = 12$ $6 \times 5 = 30$

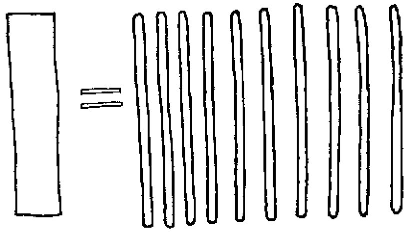
2. Children can make a 0 to 9 matrix on a square ruled copy and make their own table sheet by placing broomsticks criss-cross and counting the number of junctions. Children who have learnt to count should be encouraged to make their own table sheets.

0	1	2	3	4	5	6	7	8	9
1									
2			6						
3									
4			12						
5									
6					30				
7									
8									
9									

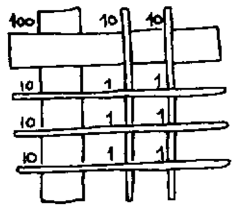
3. This picture shows how the abstract concept of multiplication by zero can be concretised.



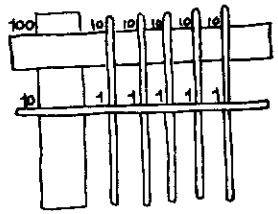
4. Multiplication of two-digit numbers would mean counting too many junctions. So, ten broomsticks can be represented by one card strip.



5. Criss-cross of two strips will be 10 x 10 = 100, while that of a strip and a broomstick will be 10 x 1 = 10. Add up the sum of all the junctions to get the multiplication value.



$12 \times 13 = 156$



$15 \times 11 = 165$

This section is inspired by the fascinating work of P. K. Srinivasan of Chennai.

Aeroplane Wing

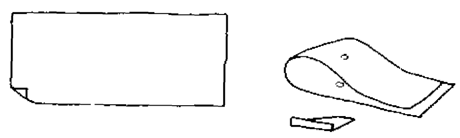
What makes an aircraft fly? How does the aircraft's wing produce lift? You can find this by making a model of part of an aircraft wing.

You will need

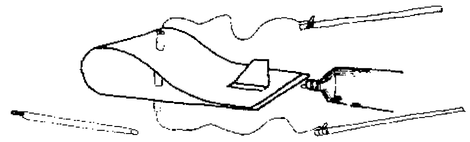
Paper	Empty ball pen refill or soda straw	
Glue	Thread	Two sticks

Here we go

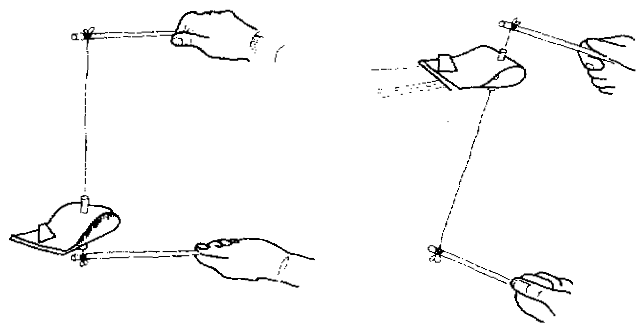
1. Cut a piece of paper 20cm-long and 10cm-wide. Bend it in half and stick the edges together. Run a fold along the edge with your fingernails so that it bends, curved at the top and almost flat underneath. The flat end of the wing is the leading edge, and the thin edge is the trailing edge.



2. Make a hole straight through both parts of the wing about 3cm from the leading edge. Pass a piece of empty ball pen refill or soda straw through it and fix it with a dab of glue.



3. Stick a piece of paper on the centre line of the trailing edge. This fin will stand vertically on the trailing edge and help in stabilising the wing. Pass a thin thread through the refill and fix it on two sticks.
4. As you swing the sticks through the air, the wing will rise on the thread. The top curved portion of the wing is longer than the bottom portion, so the air moving over the top has further to go and, therefore, it moves faster. This produces a lower pressure on top of the wing producing lift. This is how the wing helps an aeroplane to rise in the air.



Spring Bangle Balance

Plastic spring bangles are available in attractive colours and come cheap. These spring bangles can be used as low stiffness springs for a number of simple experiments.

You will need

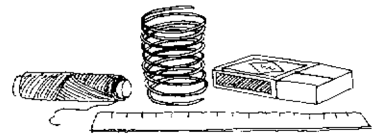
A spring plastic bangle (like a Slinky)

Thread	Empty matchbox
Coins	A scale

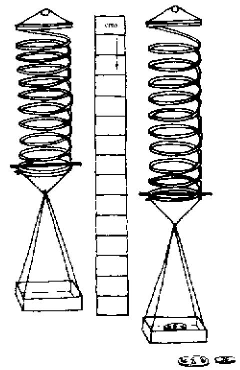
Here we go

1. Tie a thread loop to hang the bangle by a nail. Hang a matchbox drawer at the bottom for the pan. Fix a broomstick on the bottom coil to act as the indicator. Mark the initial position of the indicator with the pan empty. Coins have standard weights. A 50-paisa coin weighs 5gm and 25 paisa 2.5gm.

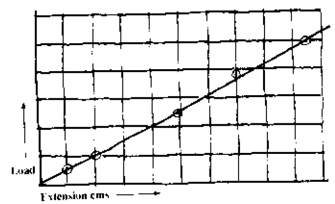
Place coins for different weights on the pan and measure the extension in each case.



2. When the load is plotted against the extension on a graph paper, almost a straight line is obtained, proving Hooke's Law—within elastic limits, the stress is proportional to the strain. The calibrated spring bangle can also be used as a very sensitive spring balance as it has a measurable response to even a one-gram load.



Hold the top thread loop and oscillate the spring bangle with the empty pan. Note the time taken for ten oscillations. Repeat this with different weights in the pan.



Press Button Switch

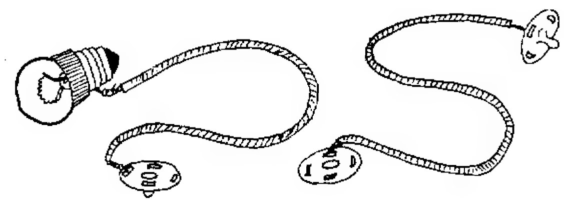
Make this simple switch and light up your room when there is a power cut.

You will need

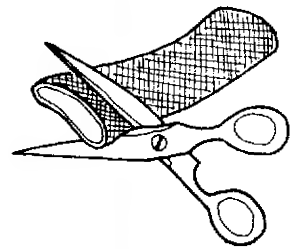
Brass press buttons	Torch bulb
Torch battery	Wires
An old bicycle tube	

Here we go

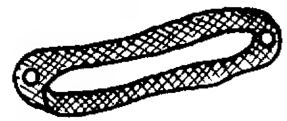
1. Connect one wire to the bulb and button and the other to two halves of the press button.



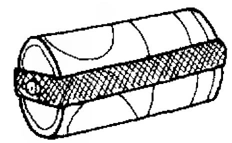
2. Cut a 1cm-wide rubber band out of an old cycle tube.



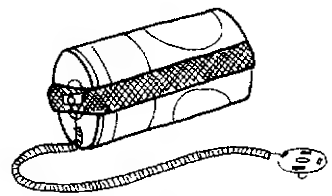
3. Cut two circular notches at diametrically opposite ends of this band.
4. Stretch and slip the band on the battery. The positive top of the battery top sits in one notch.

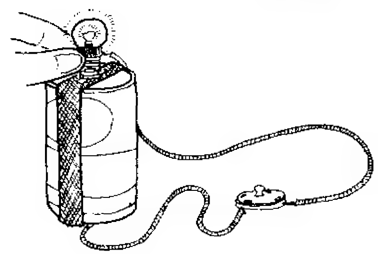


5. A press button half with the raised part sits in the other rubber notch at the battery bottom.



6. Place the bulb on the battery top and snap close the two parts of the press button to close the switch, and light the bulb.





Vivek Paraskar of Eklavya, Ujjain, found this ingenicus solution to the switching problem. He used press buttons. They are made of brass, so they never rust.

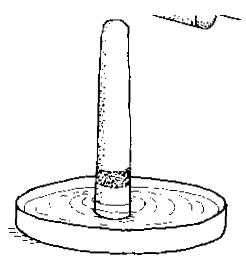
Chromatography

While having fun with colours, you can also master the techniques used for separating mixtures.

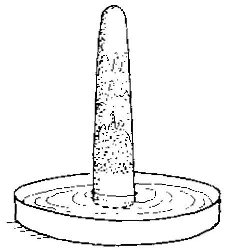
You will need

Black, red, blue and yellow ink
A stick from a broom
A strip of blotting paper | Cotton wick
Chalk | A lid | A glass

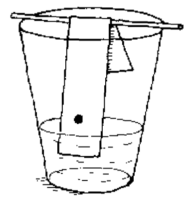
Here we go



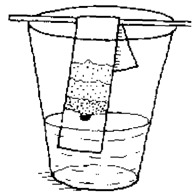
1. Mix a few drops of black, red, yellow and blue ink. Place a few drops of this ink on a chalk about 5mm from the thick end. Dry the chalk in sunlight. Now stand the chalk in a lid containing water. The ink band should not be in direct contact with the water.



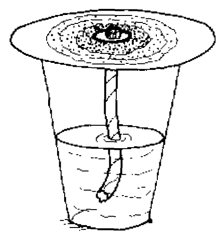
2. After some time the water rises up the chalk and the different colours are separated in distinct bands.
3. Take a strip of blotting paper and place a small drop of the mixture ink on it about 1cm from the end. Dip the strip in water and fold and rest the other end on a broomstick on a glass. Ensure that the water level in the glass is below the ink dot.



4. After some time, as the water rises on the blotting paper, the colours of the ink mixture are dispersed in distinct bands.



5. Make a 5mm hole in the centre of a circular blotting paper. Mark a circular mixture ink ring slightly away from the hole. Place a wet cotton wick in the hole and rest the paper on a tumbler with the wick dipping in water. After a while the ink mixture is dispersed in beautiful circular bands. This technique known as chromatography is used for separating mixtures in several industrial processes.



Tree Nameplates

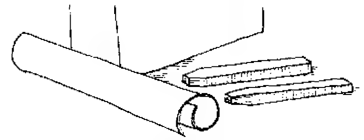
Every tree has a name though we seldom know it. Putting nameplates on trees would be very useful public education. Normally a mild steel plate is taken and painted black. The name of the tree is painted in white and the plate is nailed to the tree. The trouble with this traditional technique is that the mild steel soon rusts because it is exposed to the elements. Within a year or two, the paint peels off.

You will need

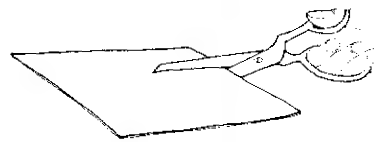
Thin aluminium sheets
Alphabet punches
Scissors
A plank of wood

Here we go

1. A simple way of making tree name plates is by punching thin aluminium sheets with alphabet



punches. These steel chisel-like pu available in various sizes in hardware Cut a 10 cm x 5 cm piece of aluminiu enough to be cut with a scissors. Keep on a plank of wood and using the punches, emboss the name of the tre



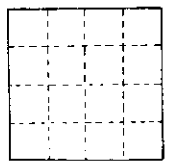
These embossed aluminium tree nameplates never rust and there is no paint to peel off. They require no maintenance. Schools could easily take up this project.

Tangram

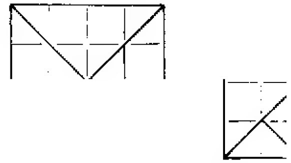
This is a thousand-year-old Chinese puzzle. Cut any size square into seven pieces by following the steps given below. Now assemble the seven pieces to make shapes of animals, birds, human beings and anything else you want. In each case, all seven pieces have to be used.

You will need
A square cardboard sheet

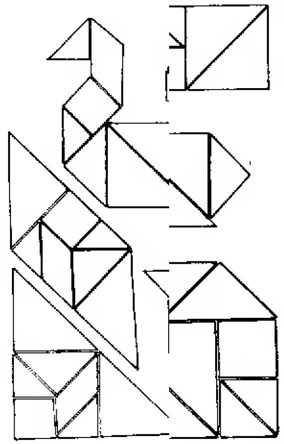
Here we go
1. Mark 16 small squares in a cardboard square of edge 10cm.

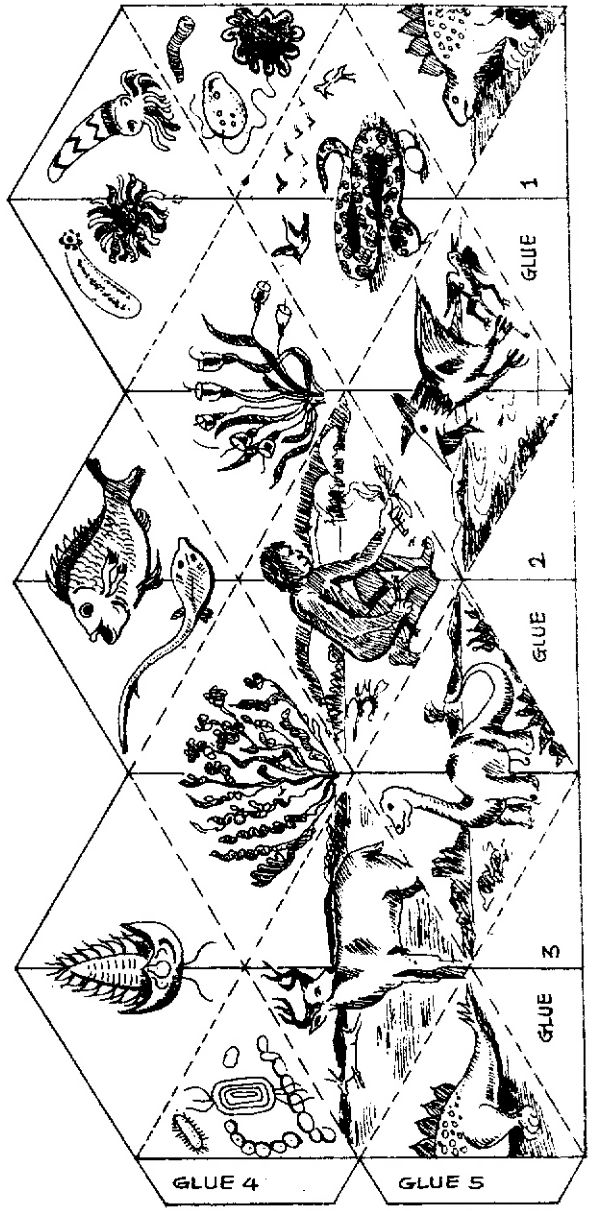


2. Draw the lines as shown.



3. Cut along the line:even pieces of the tangram.

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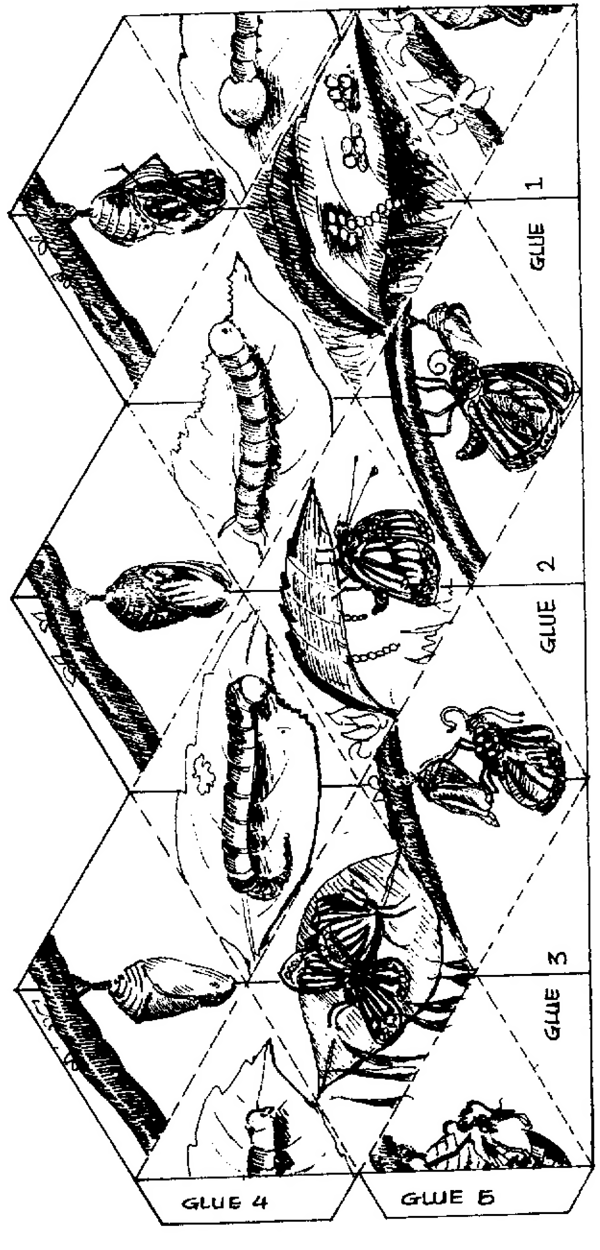
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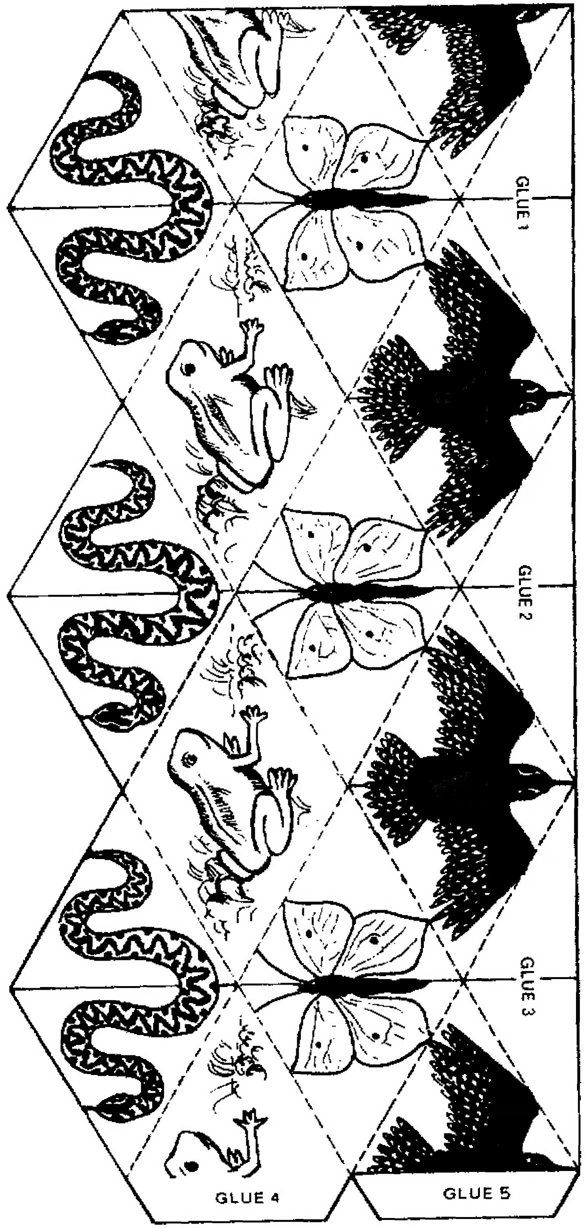
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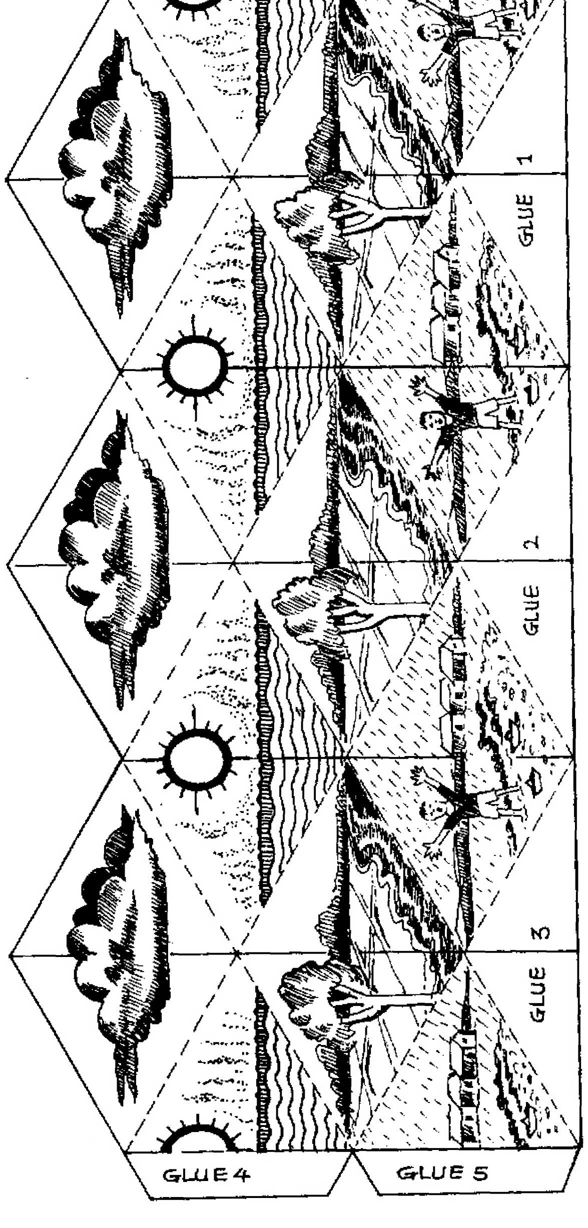
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